<Session 5: Wildlife Tracking I>A Study on Small Generator of Electromagnetic Coil for Subcutaneous Implantation

AUTHOR(S):

Nakajima, I; Kitano, T; Nakada, K; Hata, J; Ta, M

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A Study on Small Generator of Electromagnetic Coil for Subcutaneous Implantation

Nakajima I[1], Kitano T[1], Nakada K[1], Hata J[1], Ta M[2]

[1]Tokai University School of Medicine, Isehara City, Japan

[2]Tasada Works, Takaoka City, Japan

Abstract

We have developed an electromagnetic generator to bury in subcutaneous area or abdominal cavity of the birds. As we can't use a solar battery, it is extremely difficult to supply a power for subcutaneous implantation such as biosensors under the skin due to the darkness environment. We are aiming to test the antigen-antibody reaction to confirm an avian influenza. One solution is a very small generator with the electromagnetic induction coil. We attached the developed coil to chickens and pheasants and recorded the electric potential generated as the chicken walked and the pheasant flew. The electric potential generated by walking or flapping is equal to or exceeds the 10 V peak-to-peak at maximum. Even if we account for the junction voltage of the diode (300 mV), efficient charging of the double-layer capacitor is possible with the voltage doubler rectifier. If we increase the voltage, other problems arise, including the high-voltage insulation of the double-layer capacitor. For this reason, we believe the power generated to be sufficient.

Keywords: subcutaneous sensor, avian Influenza, Japanese pheasant

Introduction

Conventional subcutaneous sensors are not exposed to sunlight and require an external energy source, such as microwaves. Our goal is to develop a small power-generating device that harnesses the kinetic energy of walking, flapping, and other movements to generate electric potential through electromagnetic induction. This article provides a brief overview of such a device.

Background

As the human population continues to expand, humans increasingly encounter birds and animals rarely encountered in the past. Exposure to and infection by special pathogens originating from rare birds and animals is a growing social problem. Implanting microcapsules into birds or animals capable of electrically detecting antigen-antibody reactions would make it possible to monitor avian influenza outbreaks (including outbreaks of strains that are merely weakly pathogenic) and other zoonotic diseases, such as West Nile fever and scrub typhus. In essence, this would establish an early warning system that issues geographical alerts for emerging diseases, making it possible to respond or even to prevent the emergence of such disease. In the case of migratory birds, implanting such a device in one bird per 100 may be sufficient to monitor an entire flock. Beyond this, some 80 billion poultry birds are grown commercially around the world. A system that implants a 10-yen antigen-antibody reaction sensor in each young bird potentially opens the doors to a vast market on the scale of 800 billion yen.

Development

Principle

Faraday's law of electromagnetic induction

Magnetic field lines indicate the direction of the magnetic field strength H; magnetic flux lines indicate the direction of the magnetic flux density B; and the total number of magnetic flux lines is the magnetic flux.

When a magnetic field of magnetic flux density B perpendicularly passes through a closed circuit of area S, the magnetic flux Φ passing through the area is expressed by the following equation:

$$\Phi = BS$$

If Φ is constant, nothing happens. If Φ changes, the electromotive force induced generates a current along the closed circuit in the direction opposite the original change in the magnetic flux. This is known as Lenz's law.

Let us denote the induced electromotive force along the closed circuit as V and define the positive direction of V as the direction of the current generating the original magnetic flux Φ. Then, V is given by the following equation:

$$V = -\frac{\Delta\Phi}{\Delta t} \quad . . . \quad (1)$$

The case of N number of turns of the coil is expressed as follows:

$$V = -N\frac{\Delta\Phi}{\Delta t} \quad . . . \quad (2)$$

Equations (1) and (2) are known as Faraday's law of electromagnetic induction. Here, the negative sign may be replaced by the positive sign, depending on how the positive direction of the electromotive force V is defined. We will assume a negative sign unless otherwise stated in the problem.

Changing the magnetic flux passing through a static coil

For example, consider a coil whose diameter is 7 mm (with cross section of 0.00385 m^2) and whose number of turns is 6,100. Assume that the magnetic flux density passing upward through the coil increases at the rate of 0.40 T (teslas) per second.

According to Lenz's law, we can calculate the induced electromotive force that generates a current to oppose this increase. Since the magnetic flux increases at 0.40 × 0.00385 = 0.00154 Wb (webers) per second, the electric potential V generated at the terminal is expressed as follows:

$$V = -N\frac{\Delta\Phi}{\Delta t}$$

= □6100 × 0.00154 = □9.394 [V]

If the magnet moves vertically according to a sine curve with respect to time, we obtain an alternating current with effective power of +/□9.39 V.

Implementation

The coil prepared for evaluation has the following specifications. A copper wire measuring 0.03 mm in diameter is smoothly wound 6,100 turns (center-tapped at 3,050 turns) around a bobbin with a hand-operated coil winding device. The magnet inserted is made of neodymium magnets (specification given in Table 1). Four magnets are serially connected along the axis to form an 8-mm long cylindrical magnet. The electric potential generated by the oscillations is amplified with an operational amplifier with an amplification factor of 2 and recorded with a small data logger (20 g).

Experiments

We attached the developed coil to chickens and pheasants and recorded the electric potential generated as the chicken walked and the pheasant flew.

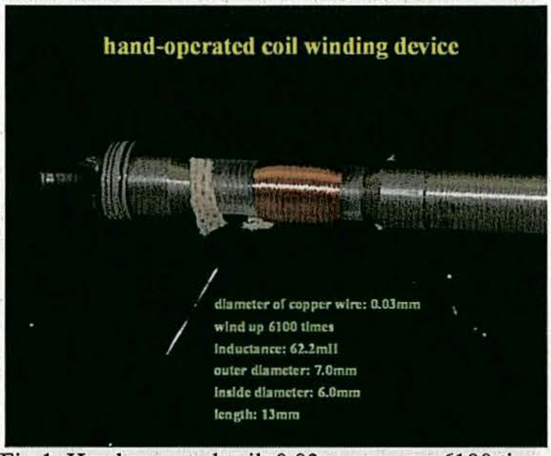

Fig.1: Hand-operated coil, 0.03mm copper 6100 times

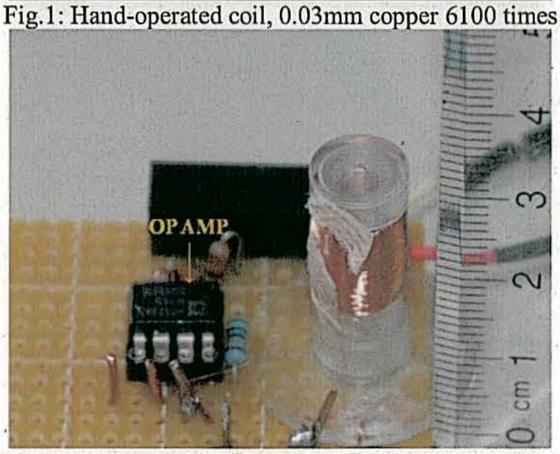

Fig2.: A magnet inside and set OPAMP(AD623) for the differential amplification

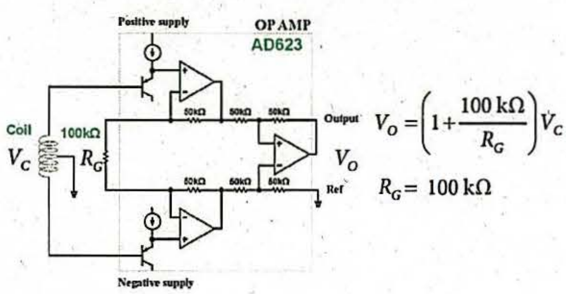

Fig.3: Connection diagram of the differential amplification

Walk:

The figure below shows the electric potential recorded as the chicken walked about.

Fig4.: Evaluation system attached (Left: Walking chicken; right: pheasant in flight)

Neodymium φ5mm×φ1.5mm×2mm (0番1種M1.4)

	abbreviated designation	SI	
Diameter	D	5	mm
Inside diameter	ID	1.5	mm
Length	L	-	mm
Wide	W	-	mm
High	H	2	mm
Error +/−	D	0.1	mm
	ID	0.1	mm
	L	-	mm
	W	-	mm
	H	0.1	mm
Magnetization	M	2	mm
Weight	Net	0.000268	kg
Surface treatment	NiCuNi	12	µm
Surface maginduction	B	304	mT
Adsorption power	F	0.383	kgf
Oppointmaginduc	Bd	709.2	mT
Total flux	φo	0.00001267	Wb
Coefficient	Pc	1.53	Pc
Upper limit temp	Tw	90	℃
Lower limit temp	Tw	-	℃
Materials	Neodymium	35	
Residual magnetic	Br	1170-1220	mT
Coercive force	Hcb	≧868	kA/m
Inherent coercive fo	Hcj	≧955	kA/m
Maxenergy product	BH	263-287	kJ/m3
Temp coefficient	Br	-0.12	%/℃
	Hcj	-0.55	%/℃
Heat-resistant temp	Tw	≦80	℃
Curie point	Tc	310	℃
Density	ρ	7.5	kg/m3

Table 1: Specifications of the magnet, use as a columnar magnet connected tandemly four (column of total 8mm in length)

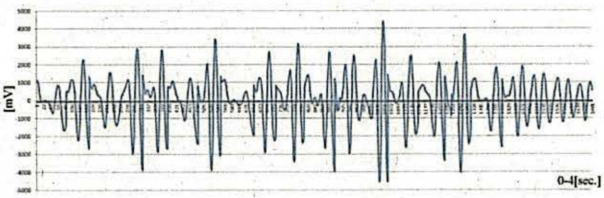

Fig5.: Voltage generated by walking chicken

Flight:

The flight experiments (outdoor) were performed with Japanese pheasants carrying small data recorder or hi-vision camera on their back. We have tested total 13 Japanese Pheasants(female) .

A) It is equipped with a hi-vision camera of 32g and analyzed the vibration with the motion pictures during their flight.

B) Recorded and analysis of the motions during flight and walk with 3 axis accelerometers.

Discussion

The electric potential generated by walking or flapping is equal to or exceeds the 10 V peak-to-peak at maximum. Even if we account for the junction voltage of the diode (300 mV), efficient charging of the double-layer capacitor is possible with the voltage doubler rectifier. If we increase the voltage, other problems arise, including the high-voltage insulation of the double-layer capacitor. For this reason, we believe the power generated to be sufficient.

The coil developed for evaluation in this study is relatively large for implantation, although it can still be implanted in an adult chicken or other bird of similar dimensions. Further reductions in size will allow use with medium-sized migratory birds such as gulls.

Although the average current obtained with the evaluation coil is approximately 0.1 mA, electric potential is continuously generated throughout the day. Thus, we estimate one antigen-antibody reaction test could be performed roughly once per week. Of course, transmitting data to an external device will require a communication device fitted to the back of the bird or animal. Because we developed a physical simulator such as figure 6, we intent to analyze the correlation of generation voltage and flap. In future, creating miniature of the coil for small birds, we have to perform the optimization of the from maximum quantity of electricity.

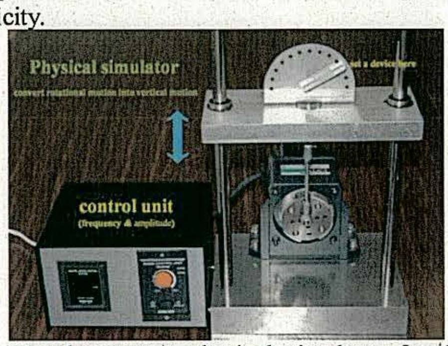

Fig.6: Development a physical simulator for flap of birds

Note: The reflection mechanism of the magnet and the equivalent spring constant value are not disclosed for reasons involving pending patent applications.

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Author's Address

Isao Nakajima, M.D., Ph.D.(medicine), Ph.D.(applied informatics)

Department of Emergency Medicine and Critical Care, Tokai University School of Medicine

Email:js2hb@ets8.jp